Abstract—The difficulty of double-polarized one-dimensional phased-array antenna with large-angle scanning is to realize two differently polarized radiating elements in the interval of nearly half wavelength. In the X-band, the spacing should be controlled within 17 mm. Under the technical requirements of power, efficiency and environment, based on the comparison of microstrip oscillator, SIW slot, waveguide slot and single-ridge waveguide slot, it is determined that a double-polarized antenna row element consisting of the single-ridge waveguide broad-wall slot with vertically polarized waves and rectangular waveguide narrow-wall slot with horizontally polarized waves realizes a one-dimensional scanning of phased array on the vertical. The computer-aided method is used to calculate the active admittance in the crack and the gap conductance function. Finally, the feasibility of the design is verified by electromagnetic simulation.

Keywords—Single ridged waveguide; Phased array; Dual-polarization antenna

I. INTRODUCTION

In recent years, phased-array radar technology has developed rapidly with the continuous maturity of TR component technology and the rapid decline in cost. Because of the large number of phased-array elements for two-dimensional scanning, cost is still an obstacle for the development. For many engineering applications, a one-dimensional phased-array scanning and mechanical scanning phased-array antenna can be competent. The antenna, as a key part of phased-array radar, requires multi-polarization, large scanning angle, and high resolution[1-3]. This paper designs the low-lobe double-polarized one-dimensional phased-array antenna in X-band for application requirements.

II. GOALS AND SOLUTIONS OF ANTENNA DESIGN GOALS AND

The designed goal of this paper: Frequency: X-band; bandwidth is 3%; VH orthogonal dual polarization; Gain: ≥ 30dB; Beam width: Elevation ≤ 8°, Azimuth ≤ 3°; Input peak power of line element: 200W; Average power: 20W; Total peak power: 6400W; Total average power: 640W; Elevation angle of phased-array scanning: ± 50°, Azimuth angle of mechanical scanning: 360°.

According to the requirements, SIW slots, microstrip oscillator arrays, rectangular waveguide broad-wall slots and narrow-wall slots, single-ridge waveguide broad-wall slots and narrow-wall slots are compared. Finally, the design is adopted where broad-wall slot array of single-ridged waveguide radiates vertical polarization and narrow-wall slot array of rectangular waveguide radiates horizontal polarization. Because the bandwidth of the design is not broad, the feeding of the row elements adopt traveling wave array scheme.

III. ANTENNA DESIGN

A. Design Process of the Row Elements

Since the waveguide array of the series feed has the phenomenon that the beam is directed to scan with frequency, the vertically polarized and the horizontally polarized row elements must maintain the same element electrical spacing, that is to maintain equal the waveguide wavelength and gap spacing, so that the both azimuthal beam directions are consistent. That is, the waveguide wavelength of the single-ridged waveguide is equal to the rectangular waveguide’s. The gap spacing of the single-ridged waveguide is equal to the rectangular
waveguide’s. So the sizes of two different waveguides are selected.

1) Design of the single ridged waveguide and non-standard rectangular waveguide

According to the reference [7], the dimensions of the single-ridge waveguide are shown in Table 1:

<table>
<thead>
<tr>
<th>Table 1. THE SIZE OF SINGLE RIDGED WAVEGUIDE</th>
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<tr>
<td>Para.</td>
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<tr>
<td>-------</td>
</tr>
<tr>
<td>Value (mm)</td>
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<tr>
<td>Para.</td>
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<tr>
<td>Value (mm)</td>
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</tbody>
</table>

Taking into account factors such as array spacing, power capacity and waveguide wavelength, the sizes of the non-standard rectangular waveguide: a wide wall aₓ=0.74λ₀ and a narrow wall bₓ=5mm.

2) Calculating gap spacing of the row element

According to the reference [5], it is determined that the longitudinal slot spacing of the waveguide is dₓ=0.61λ₀ and the beam inclination angle θ=5°.

3) Determining the distribution of the gap conductance and gap conductance function

According to the gain, overall size and the azimuthal beam width requirements, the design adopts Taylor function distribution, the number of selected slots is N=60, and then Taylor line source that the number of sidelobe is 5, and the sidelobe level is -35dB is designed[5].

The relationship between the offset distances of broad-wall slots of single-ridge waveguide and the gap conductance is obtained from the reference [5]. The relationship between the depths of the narrow-wall slots of non-standard rectangular waveguide, the angles and the gap conductance is obtained from the reference [6].

B. Design and Simulation of Array Antenna

The row elements are grouped to form arrays shown in Fig.1. According to the requirements of gain and beam width, 16 row elements of single-ridge waveguide broad-wall slot along the y direction and 16 row elements of non-standard rectangular waveguide narrow-wall slot are alternately arranged, and both of 16 TR components respectively excite vertical and horizontal polarization. 60 slots are designed on each waveguide along the x direction. The simulation results show that when dₓ=0.21λ₀, the gain reaches the optimum value.

Fig.1 Partial view of the antenna array (a) Front view; (b) Vertical view

The row elements of ①,② in the middle of the array are selected for simulation, and the excitation ports are numbered 1 and 3. The terminal is connected to the matching load and ports 2 and 4 are set respectively. It can be seen from Fig.2 that |S₁₁| ≤ 30dB, |S₃₃| ≤ 30dB, the isolation of the two ports is better than -60dB within the frequency band.
Fig. 3 is the pattern of the two row elements at the center frequency. It can be seen that the first sidelobe is less than -33 dB. The cross-polarization level of single-ridge waveguide broad-wall slot array is less than -40dB, but the non-standard rectangular waveguide narrow-wall array’s is -15dB, which is an inherent characteristic of the tilted gap. In addition, both row elements will have grating lobes and larger back lobes in a certain direction. This is because the lateral dimension of a single waveguide is too small, and the current on the surface of the waveguide is diffracted.

Finally, the entire array is simulated with each port to be excited with different phases[4]. *Ph0* indicates that the maximum radiation direction of the phased-array is 0°. *Ph1* represents the maximum scanning angle of the phased array. Fig. 4 shows the pattern at the center frequency, which clearly shows that the scanning angles of both polarization directions are ±50°. Fig. 5 shows the cross-polarization become worse in elevation, when *d* increases by 1mm. Table II shows that design of the antenna meets the requirement.
Table II. SUMMARY OF ANTENNA PERFORMANCE

<table>
<thead>
<tr>
<th>Polarization</th>
<th>Vertical Polarization</th>
<th>Horizontal Polarization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fre. (GHz)</td>
<td>9.3 9.4 9.5</td>
<td>9.3 9.4 9.5</td>
</tr>
<tr>
<td>0° Gain (dB)</td>
<td>33.6 33.7 33.8</td>
<td>33.9 34 34.1</td>
</tr>
<tr>
<td>50° Gain (dB)</td>
<td>30 30 30.4</td>
<td>30.3 30.4 30.4</td>
</tr>
<tr>
<td>Req. Gain (dB)</td>
<td>30 30 30</td>
<td>30 30 30</td>
</tr>
<tr>
<td>BW (°)</td>
<td>Sim. y 7.3 7.2 7.2</td>
<td>7.3 7.2 7.2</td>
</tr>
<tr>
<td></td>
<td>Req. y 8 8 8</td>
<td>8 8 8</td>
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<tr>
<td></td>
<td>Sim. y 2.2 2.2 2.1</td>
<td>2 2 2</td>
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<tr>
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<td>Req. x 3 3 3</td>
<td>3 3 3</td>
</tr>
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</table>

IV. SUMMARY

In this paper, an dual-polarized one-dimensional phased array antenna based on single-ridge waveguide is designed in X-band. The simulation results show that the phased array antenna can scan up to ±50° and the sidelobe level is as low as -30 dB. The antenna with a larger scanning angle, lower sidelobe level, higher power capacity and lower cross polarization has higher engineering practical value.

REFERENCES